HEP Pattern Recognition with an Automata Processor

Fermilab
in collaboration with THE CENTER FOR AUTOMATA PROCESSING, UNIVERSITY OF VIRGINIA

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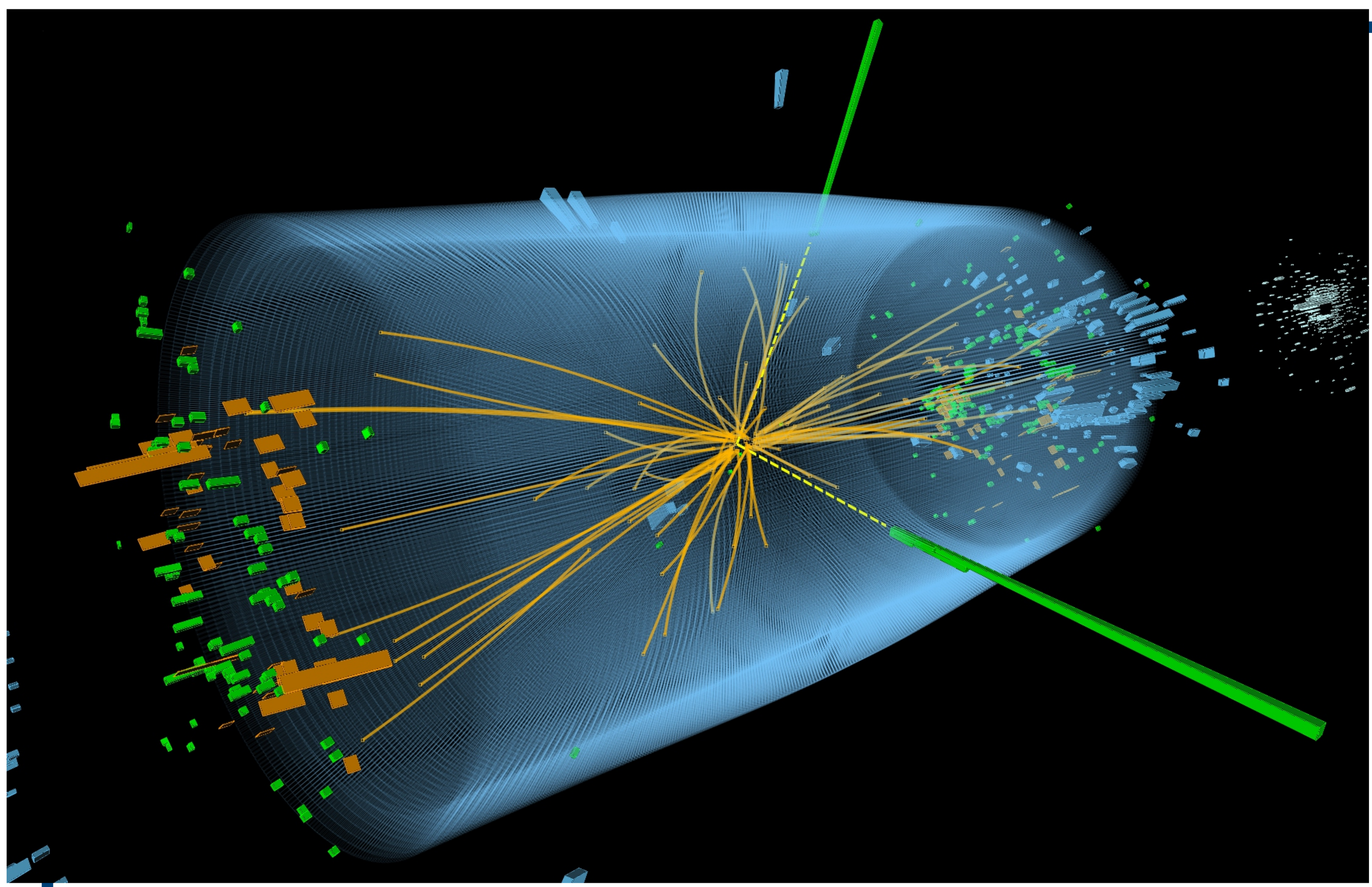
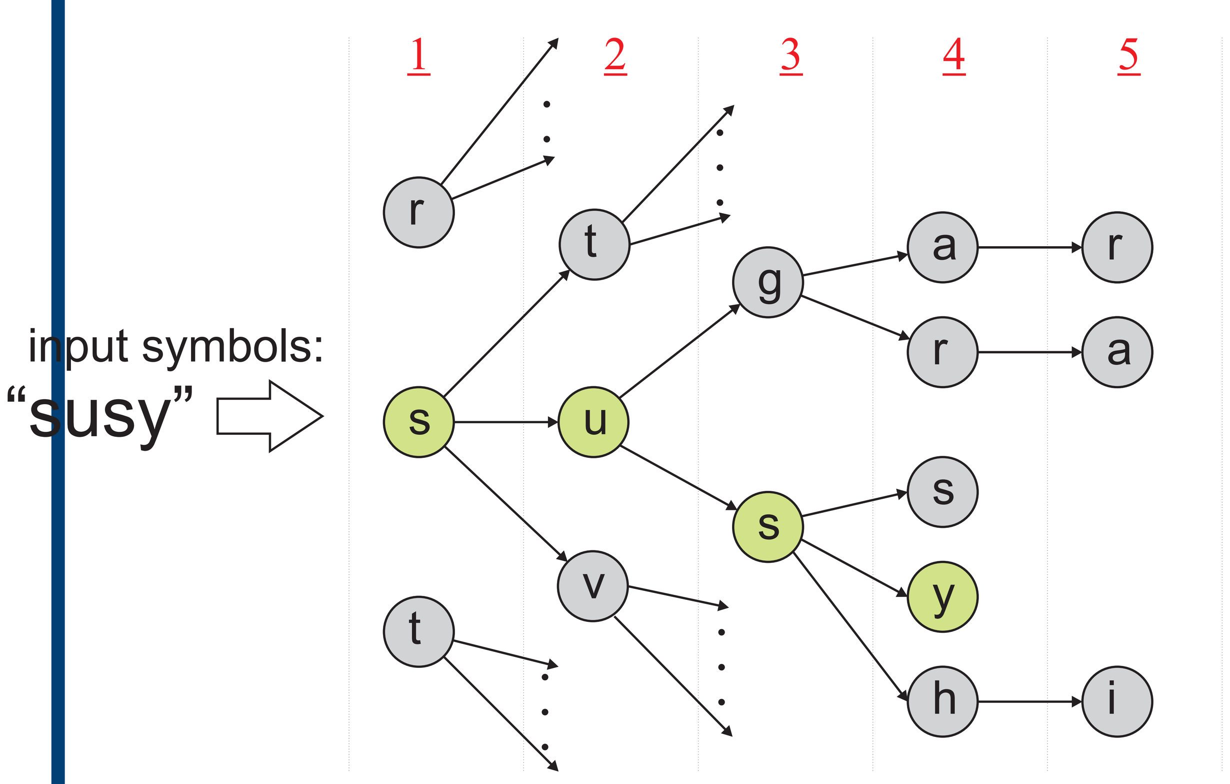


Candidate 8 TeV photon-photon event. Source: CMS Experiment at the LHC, CERN, 2012.

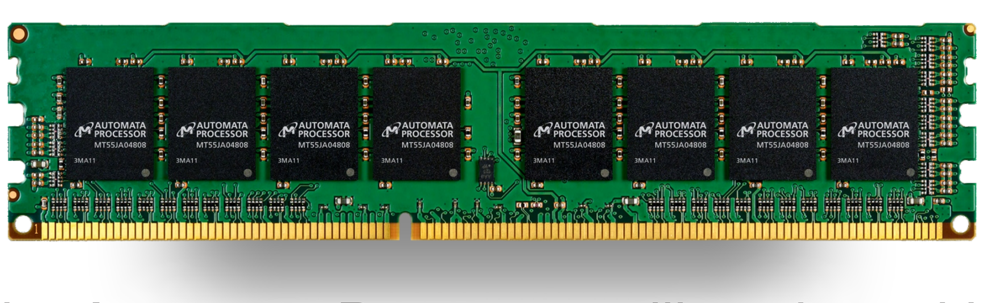
Introduction

HIGH Energy Physics (HEP) experiments today typically sift through millions of interactions in search of that proverbial needle in a haystack that confirms existing theories or provides clues to new physics. Pattern recognition plays a crucial role in this task of digging out those rare and interesting events buried deep in the haystack of mundane events. The trend with each new generation of experiment towards more complex event topologies and higher particle densities has made this task increasingly more difficult. The conventional computing technologies used so far to address this will become less effective as we approach the end of Moore's law. This project looks at the Micron Automata Processor, a unique commercial pattern search engine designed for today's data-centered economies, as a viable alternative to the growing demands of pattern recognition

Micron Automata Processor

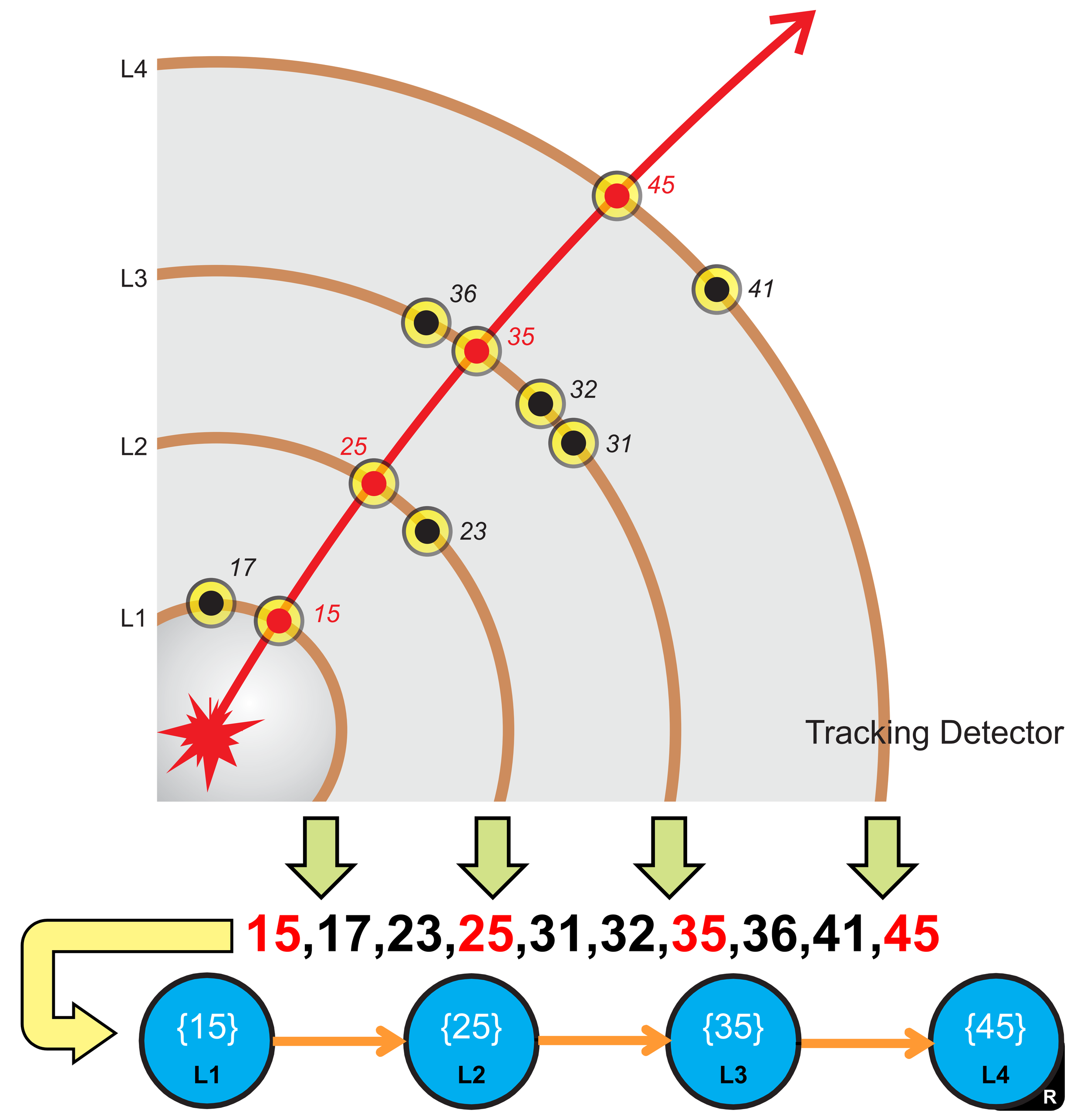


Automata-based dictionary search for the acronym "SUSY".



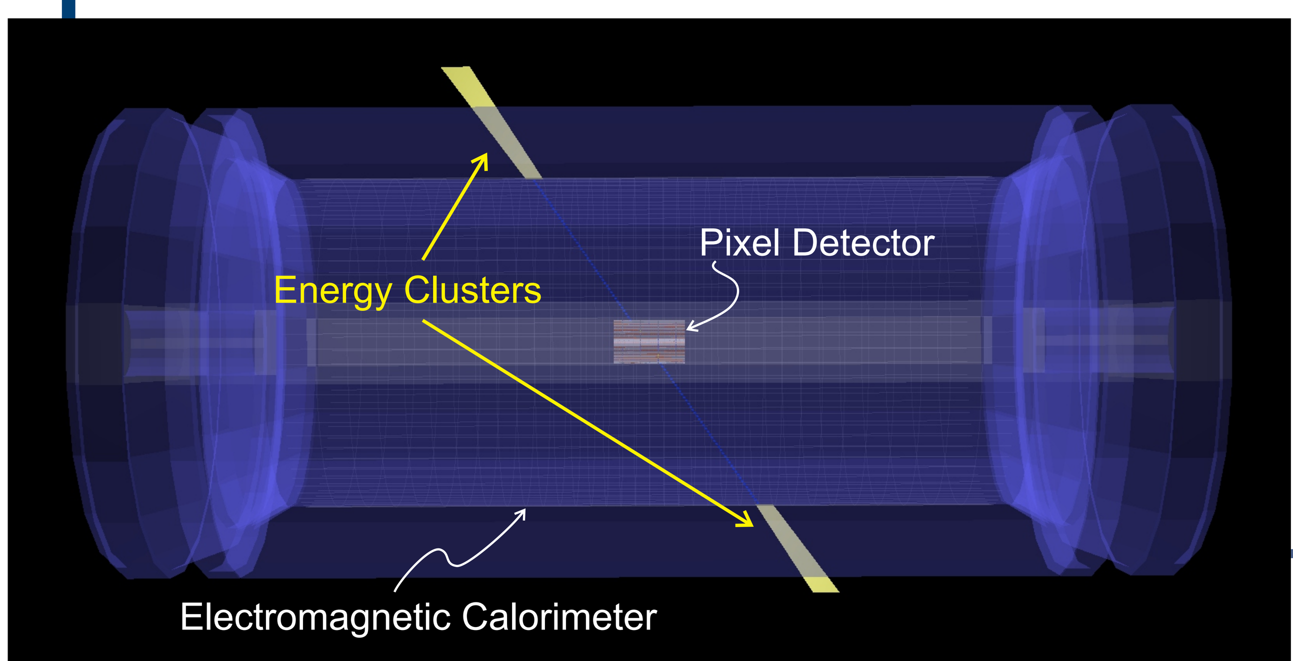
The Automata Processor will packaged in 8-chip DIMM modules with a DDR3-like interface. Source: Micron Technology, Inc.

The Micron Automata Processor is the first direct implementation of a non-deterministic finite automata in hardware. It consists of 48K basic entities known as State Transition Elements (STEs) embedded in a reconfigurable 2D fabric. The programmable symbol recognition capability of each STE and the ability to define the interconnections between them allow the creation of custom automata networks that simultaneously apply thousands of rules to find patterns in data streams at a constant rate of 1Gbps.

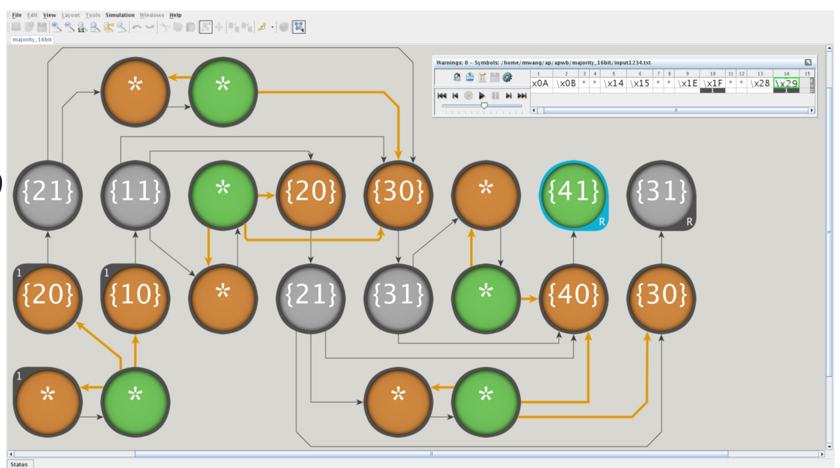


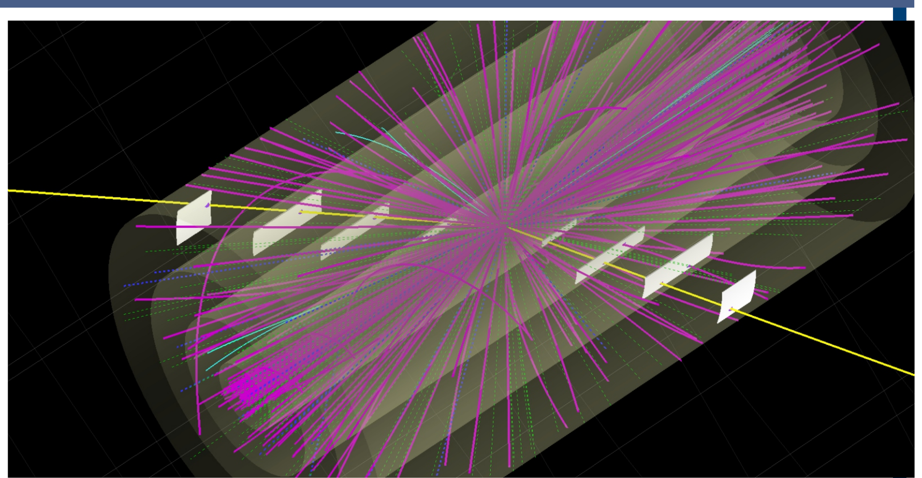
The symbols recognized by the STEs need not be restricted to characters in regular expressions. They could just as well represent other quantities like the coordinates of charged particle trajectories, allowing their novel application to track finding in the particle detectors of HEP experiments.

Proof of Concept HEP application



Automaton representing a track pattern allowing up to one layer with a missing "hit".





Rare physics processes of interest often leave signatures in the detector marked by the presence of an isolated fermion like an electron. The ability to accurately identify events containing such electrons can make it easier to find the needle in the haystack. To investigate the feasibility of the Micron AP for HEP pattern recognition, we consider a possible electron trigger for the CMS experiment at the LHC as a test case. We implement this trigger on a virtual detector consisting of two sub-detectors representing the CMS pixel detector and electromagnetic (EM) calorimeter. Both electrons and photons, which are EM particles, leave energy deposits in the EM calorimeter. However, only charged particles such as electrons leave hits in a tracking detector like the pixel detector while neutral particles like photons do not. The function of an electron trigger is to find events with energy depositions in the EM calorimeter associated with a track in the pixel detector.

When an event is detected with significant energy deposition in the EM calorimeter, all the hits in a region of the pixel detector through which the EM particle could have traversed are read out sequentially by layer. These hits are presented to the automata which contains a bank of all the possible track patterns within the region. The hits are simultaneously compared against all those in the pattern bank and a report is generated when a particular sequence of hits matches those in a stored pattern. Each hit is compared against those in the entire bank in exactly two symbol cycles since our hits are represented by 16 bit addresses and the AP uses a native alphabet size of 8 bits. This means that the time to find track matches only depends on the number of input symbols and not on the size of the pattern bank. This makes the Micron AP ideally suited to deterministic low-latency applications such as an online HEP trigger.

Operated by Fermi Research Alliance, LLC under Contract No. De-AC02-07CH11359 with the United States Department of Energy. Research funded through the Fermilab LDRD Program.